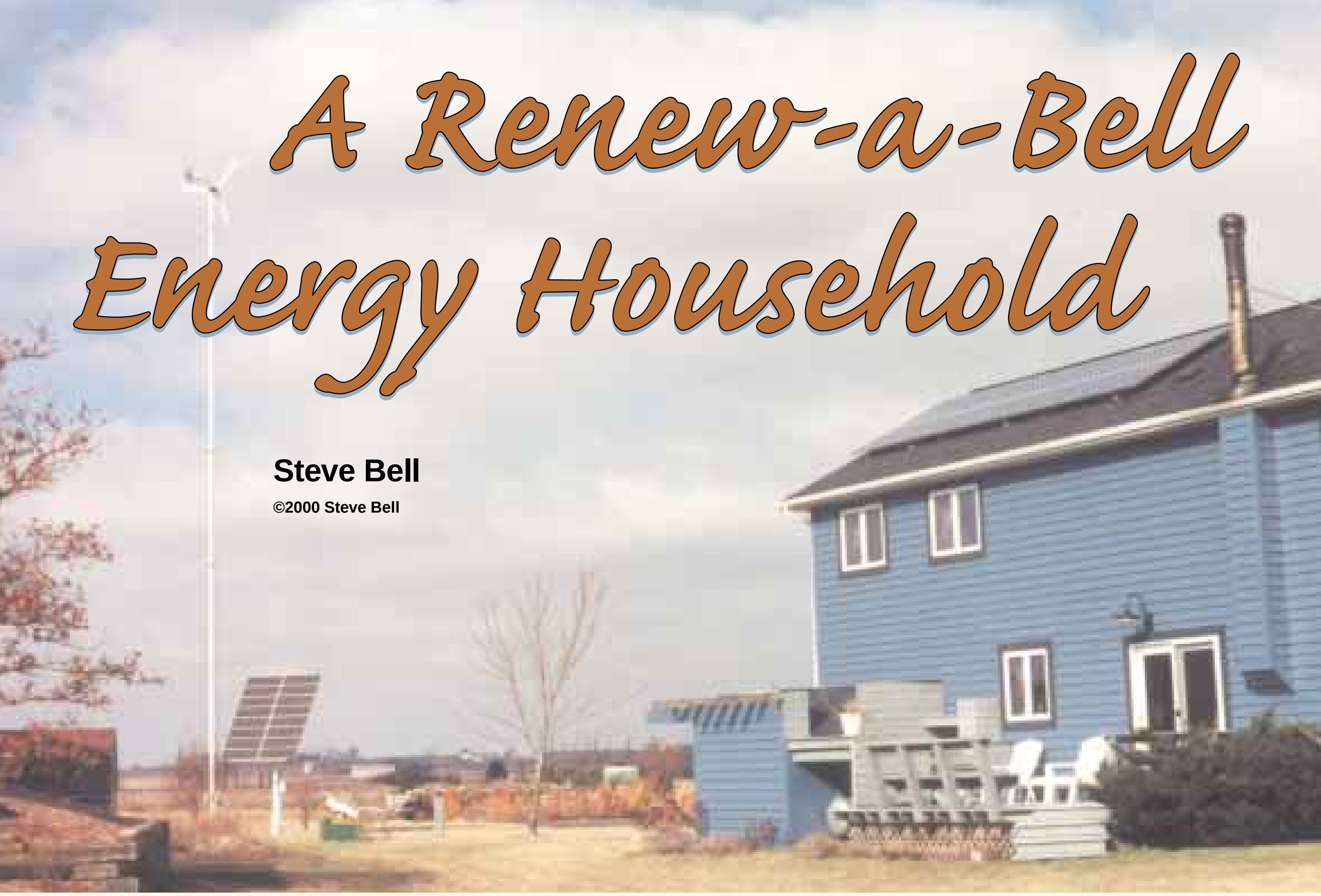
A Renew-a-Bell Energy Household

Steve Bell



Steve and Jan Bell's home with 2,100 watts of roof-mounted PV, 880 watts of tracked PV, and 3,600 watts of wind power.

Almost twenty years ago, my wife Jan and I decided we wanted to take more control and responsibility for our lives. We wanted to live in greater harmony with ourselves and nature. We wanted to live lives that lifted our spirits. We were seeking a place that would help us live in a better, more uplifting way. In the mid 1980s, we uprooted our lives, and moved to the tiny village of Stelle, Illinois. Since then, we have been learning what it means to be more responsible, spiritual beings.

Passive Solar Home

In 1986, we built our passive solar, super-insulated home. The 2,250 square foot (209 m^2) house was originally all-electric, with central air conditioning and heat. It has R-28 walls, R-50 ceilings, and R-15 rigid foam insulation on the outside of the concrete basement walls.

Our normal heating is accomplished with a wood burning stove (with catalytic converter). We use two to three cords of wood per year for heating. This is not very much for a house of this size in this location. We only use the electric furnace to keep the house from freezing when we are out of town for several days or more.

The insulation on the outside of the basement walls makes the concrete walls (75+ tons) into a large thermal mass that significantly reduces temperature fluctuations. Most of the windows are on the south and east sides of the building. This allows for good solar gain during the morning and through mid-afternoon. By aiming the long south axis of the house about 20 degrees east of due south, the south wall is perpendicular to the sun at about 11 AM rather than at 12 noon. This helps with a quick morning warm-up of the house (when it is needed), and helps reduce late afternoon overheating.

The windows in all of the rooms are configured to allow good cross-ventilation. All the windows have low-E coatings to reflect infrared radiation (heat). This keeps the heat in during the winter and out during the summer. Normally, we only use the air conditioning for four to six days per summer, during hot spells when the humidity is high and it only cools off to 85°F (29°C) at night. For the rest of the time, ceiling fans are enough.

MREA Provides RE Inspiration

When we designed and built the house, we thought that renewable energy (RE) was too expensive to realistically consider. Enter the Midwest Renewable Energy Association (MREA). In the early 1990s, we started attending the annual MREA Energy Fair in Amherst, Wisconsin. We became much more educated about the realities of RE. In 1994, we started our RE system by ordering a 4 KW remanufactured direct-drive Jacobs wind turbine and a 115 foot (35 m) custom-built, tilt-up tower kit. We purchased a Trace SW4048 inverter and sixteen Trojan L-16 batteries.

By the summer of 1996, the tower and wind turbine were installed. We normally have a good wind resource from October through mid-June; during the summer, the winds are light and variable. This provided enough power in the winter months for much of our 120 VAC loads, but was very lacking in the summer months.

We decided to make our home mostly energy independent by adding PV to our RE system, and by eliminating most of the 240 VAC loads. In September of 1997, we installed sixteen Siemens SM55J modules (880 watts) on a dual-axis Wattsun tracker. In 1998, we replaced the ten year old 22 cubic foot (0.62 m^3) refrigerator/freezer with a new high efficiency 22 cubic foot Amana refrigerator/freezer (Model BR22S6) that uses 1.4 KWH per day.

Then we started planning our conversion from 240 VAC to LP gas. First, we replaced the electric cooktop with an LP unit. We are in the final stages of installing an AquaStar 125BS on-demand propane water heater. We will be using the old electric water heaters as pre-heat tanks with 48 VDC elements for dump loads. The only 240 VAC loads we will retain are the central air conditioning and a Kitchen Aid double oven. Both these loads are rarely used, but are nice to have available.

Grant Provides Incentive

In early 1999, Illinois announced its grant and rebate program. The program pays up to 60 percent of the cost of a PV system. We decided to request a grant for an additional twenty-eight roof-mounted Siemens SP75 modules (2,100 watts), along with an SW5548 inverter, two MPPT controllers, an E-Meter, a DeSulfator, and twenty-four Concorde PVX-12255 batteries. The grant was approved, but they would not cover the cost of the batteries. The program managers decided that they would not pay for a wear item that the end-user could ruin in a short number of years.

During the summer of 1999, we installed the additions, including the larger battery bank. Since then we have always produced more power than we've needed. Our electric bills are now quite low, and should drop to little more than the basic service charge when the AquaStar goes on line. Water heating is our major utility load—abundant hot water is one of our luxuries.

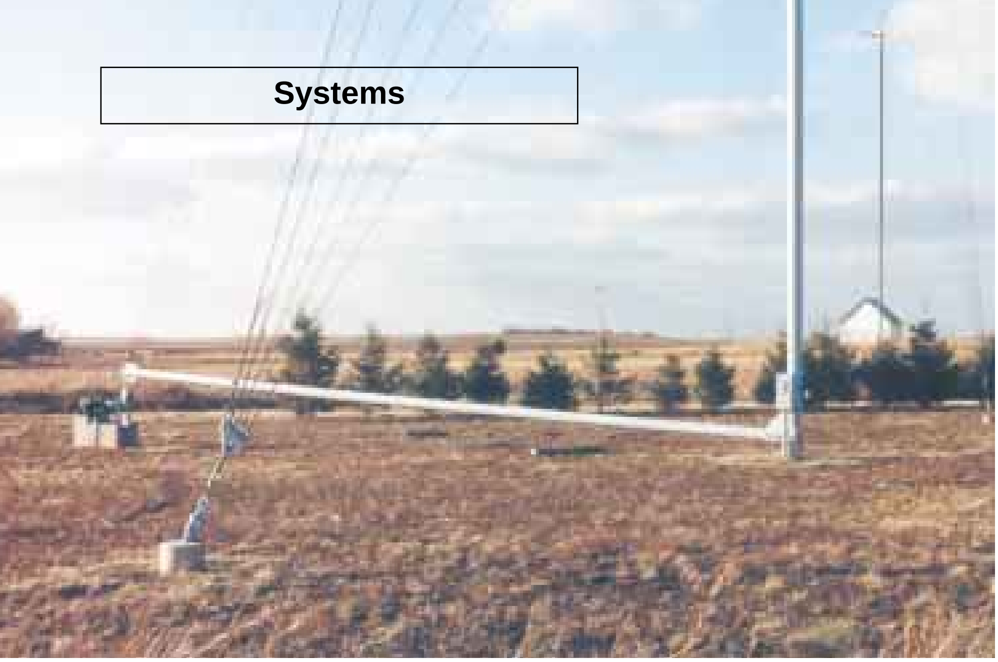
In 1994, our daily electric utility consumption was 43.6 KWH per day. Since the system upgrade last summer, our daily consumption is down to 17.1 KWH per day. Out of that total, I estimate that about 15 KWH is consumed by the water heaters. The figure is high because we are presently heating the hot water with electricity. We hope to use surplus RE energy and LP gas in the future, and four large flat-plate solar hot water panels that I plan to install someday.

Wind Turbine

The wind turbine generates a nominal 48 VDC, and is adjusted to govern at about 3,600 watts. This Jacobs "long case" wind turbine (circa 1940) has a 14 foot (4.3 m) diameter, 3 blade rotor. It's mounted on a custom-built 115 foot (35 m) tilt-up tower. The tower kit was designed by Mick Sagrillo, and assembled on the site.

I think it is the largest (heaviest) tilt-up tower that Mick has designed. It consists of four sections of 8 inch

The '40s era Jacobs wind generator (right) on its 115 foot tilt-up tower. The 10 KW Bergey Excel (left) helps power the community water treatment plant.



Five sets of guy wires attach to each anchor of the huge tilt-up tower.

schedule 40 steel pipe, with large, welded flange plates and a 7 foot (2.1 m) stub tower. There are five sets of guy wires, 16 cubic yards of concrete in the anchors and piers, and a custom made block and tackle assembly that could serve for a small crane.

The Jake is one of Mick's remanufactured units. Its output is fed underground through a pair of #2/0 (67 mm^2) USE copper cables to the battery bank. The total one-way wire run is almost 450 feet (137 m). There is a fused disconnect, with a lightning arrestor, at the base of the tower. A 150 amp, 250 volt diode at the battery end keeps the DC generator from becoming a DC motor. There is a 100 amp/50 millivolt shunt with a 100 amp analog ammeter to measure delivered power.

PV Arrays

We mounted sixteen Siemens SM-55J modules (four subarrays) on a Wattsun dual-axis tracker. Each subarray has a blocking diode on its output. The four 48 volt subarrays are wired to an individually fused combiner box (with lightning arrestor) mounted on the tracker pole. We fed the array output underground to a 20 amp DC breaker at the battery bank using about 120 feet (37 m) of #4 (21 mm^2) USE cable.

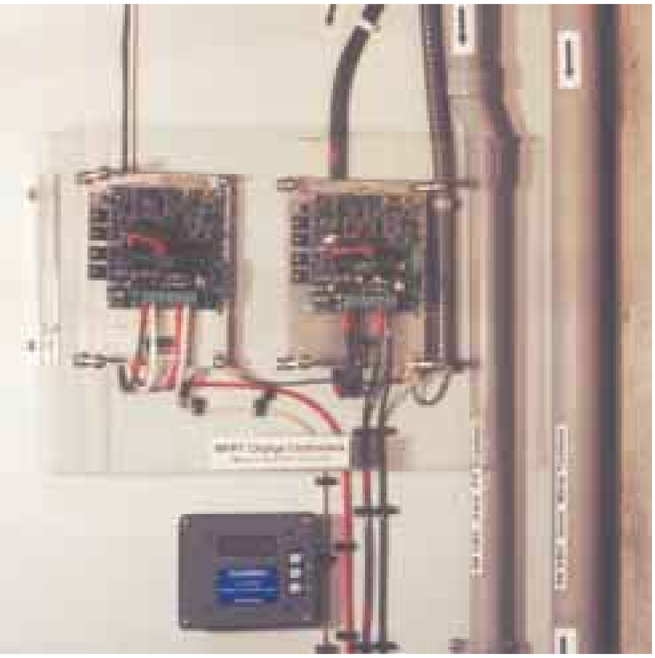
The winch, with block and tackle, at the gin pole.

There are twenty-eight SP-75 modules on our roof. Seven subarrays feed into an individually fused combiner box (with lightning arrestors). The seven outputs are combined into two main 48 volt subarrays—one of 900 watts and the other of 1,200 watts. The 1,200 watt subarray uses 70 feet (21 m) of #4 (21 mm^2) cable to connect to a Solar Converters MPPT controller (#PT48-20M) via a 60 amp DC breaker. The 900 watt subarray uses 70 feet of #6 (13 mm^2) cable to connect to its MPPT controller (same model) via another 60 amp DC breaker.

Charge Controllers

Both the outputs of the Jacobs and the 880 watt tracked PV array are connected, via blocking diodes, directly to the DC bus bars. The output of the 2,100 watts of roof-mounted PV is connected to the Solar Converters MPPT charge controllers, which connect to the DC bus bars. There are DC breakers or fused disconnects on all three charging systems.

Two MPPT charge controllers prevent overcharging by the two roof-mounted PV arrays.



A pair of C-40s (acting as diversion controllers) regulates the battery bank voltage. They dump excess power into a pair of home-built, heavy-duty, resistive hot-air heaters. The C-40s are connected to the battery bank via a 110 amp class-T fuse with parallel #2 (33 mm^2) cable from the fuse to the dump load.

Basically, I regulate my batteries with a load rather than regulating my charging source. I dump all the wind power (and the power from the PV array) directly into my batteries and then add loads to control voltage. Battery state of charge is tracked via an E-Meter, with the shunt installed between the batteries and the negative bus bar. I installed a DS-1000 battery DeSulfator (a sweep-pulsing desulfating device for larger battery banks) to help protect against sulfation.

Twenty-four Concorde SunXtender sealed absorbed glass mat batteries provide 1,800 amp-hours at 48 VDC.

Grounding

If your PVs are roof-mounted, or operate above 50 VDC, the *NEC* requires that the negative DC conductor be grounded. I have my doubts about this. If both the positive and the negative wires are allowed to “float” (are not grounded), then the only thing that they are “hot” to (read “dangerous”) is each other. You could put one wire in your mouth and stand in a puddle and not be shocked. The only danger is if you are touching both wires at the same time.

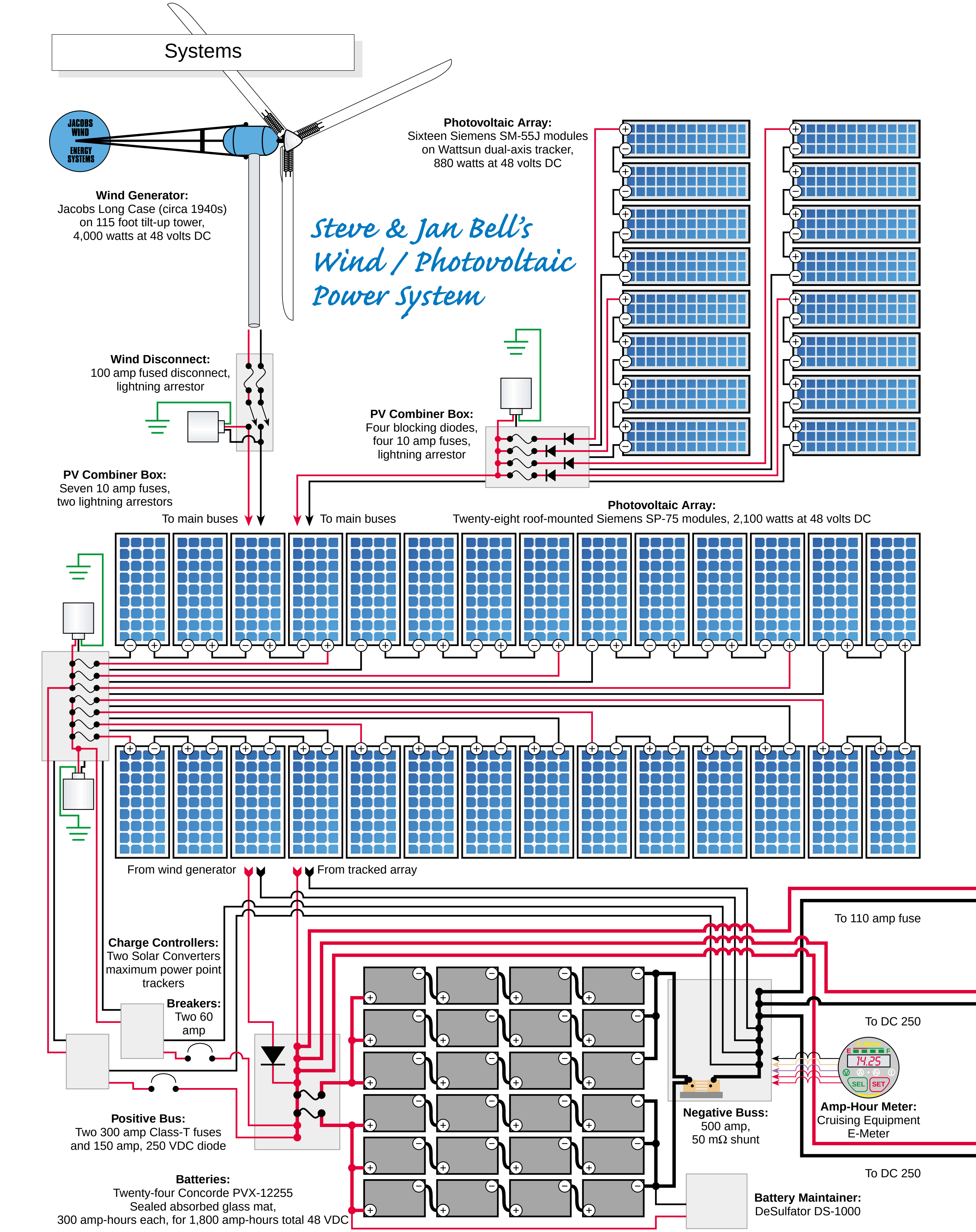
The *NEC* requires you to ground the negative leg, thus making the whole world electrically common with the negative leg. Then if you touch anything while touching the positive leg, you can get shocked. The *NEC* says this is safer.

The code requires you to ground the negative leg on roof-mounted PV arrays, and to add a ground-fault interrupter (read “extra expense”). This is to insure that the grounded negative leg does not cause a house fire should there be a failure of the grounded negative leg. With a “floating” (non-grounded) DC system, this type of fire cannot happen. I do believe in very good equipment grounding for lightning protection and safety. And very good AC grounding is important because the U.S. grid is grounded, and because many AC appliances are designed with that grounding in mind.

All the electrical equipment chassis are grounded to the AC ground. The windmill tower has ground rods on all four guy anchors and at the tower base. A #4 (21 mm^2) bare copper wire runs up the inside of the tower all the way to the top stub tower. This means that there is very low resistance from the tower top to earth ground, avoiding increased resistance where the painted tower flanges bolt together.

The PV frames, tracker rack, and pole are very well earth grounded. The roof racks and module frames are bonded and tied to the house lightning protection system, which is a very good ground. I have both Delta lightning arrestors and surge capacitors on the AC utility lines, and an arrestor on the home side of the AC (inverter AC output).

L–R: Dump load, two Trace C-40 shunt regulators, utility grid breaker, AC subpanel, grid/RE transfer switch, Trace 4048 and 5548 inverters with DC 250.


Steve & Jan Bell's Wind / Photovoltaic Power System
JACOBS WIND ENERGY SYSTEMS
Wind Generator:
Jacobs Long Case (circa 1940s)
on 115 foot tilt-up tower,
4,000 watts at 48 volts DC
Photovoltaic Array:
Sixteen Siemens SM-55J modules
on Wattsun dual-axis tracker,
880 watts at 48 volts DC
Wind Disconnect:
100 amp fused disconnect,
lightning arrestor
PV Combiner Box:
Four blocking diodes,
four 10 amp fuses,
lightning arrestor
PV Combiner Box:
Seven 10 amp fuses,
two lightning arrestors
To main buses
To main buses
Photovoltaic Array:
Twenty-eight roof-mounted Siemens SP-75 modules, 2,100 watts at 48 volts DC
From wind generator
From tracked array
To 110 amp fuse
Charge Controllers:
Two Solar Converters
maximum power point
trackers
Breakers:
Two 60
amp
To DC 250
Positive Bus:
Two 300 amp Class-T fuses
and 150 amp, 250 VDC diode
Negative Buss:
500 amp,
50 mΩ shunt
Amp-Hour Meter:
Cruising Equipment
E-Meter
14.25
SEL
SET
To DC 250
Batteries:
Twenty-four Concorde PVX-12255
Sealed absorbed glass mat,
300 amp-hours each, for 1,800 amp-hours total 48 VDC
Battery Maintainer:
DeSulfator DS-1000

Batteries

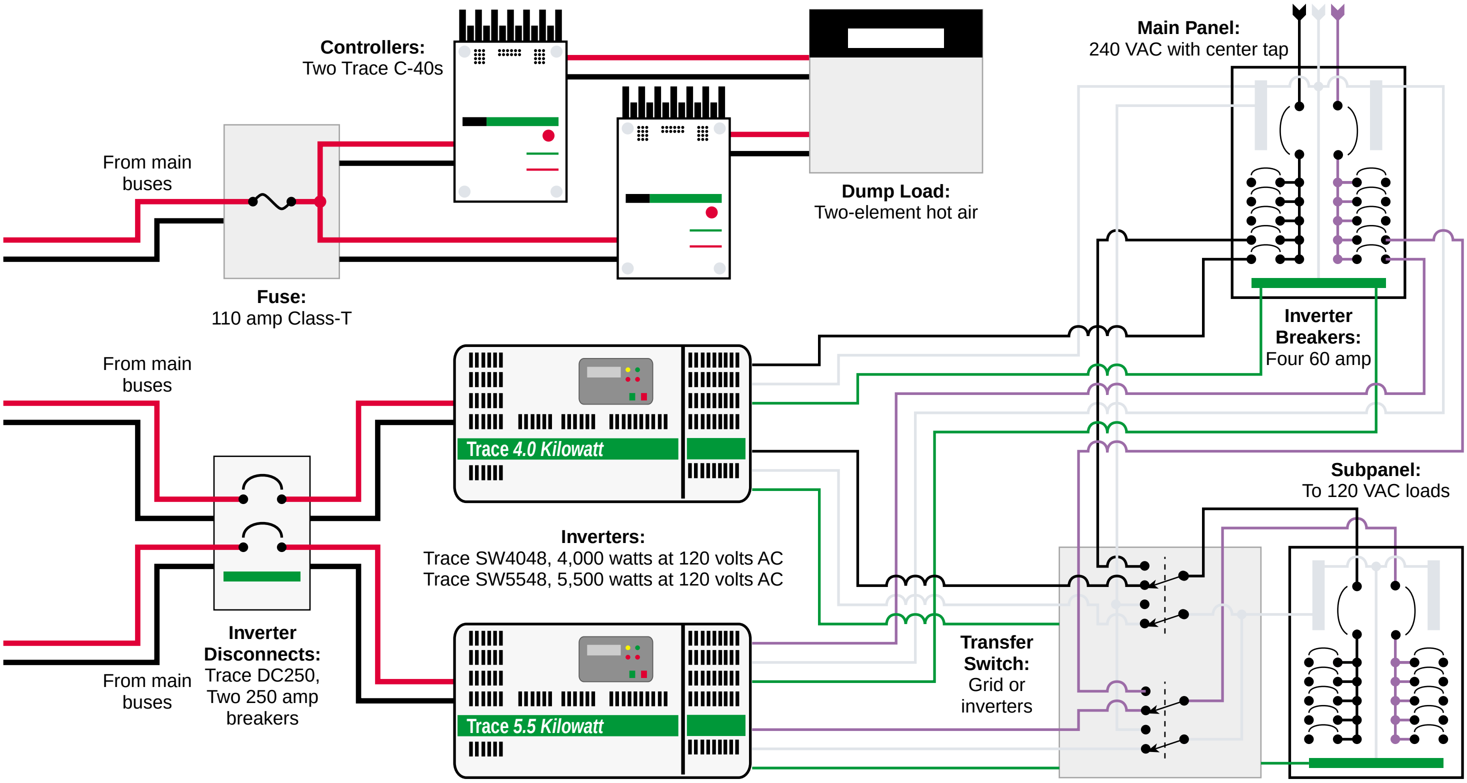
The battery bank was originally sixteen L-16s with Hydrocaps. Now it is twenty four absorbed glass mat (AGM) Concorde SunXtender PVX-12255 batteries. Each sealed battery is 12 VDC, 300 AH at the 100 hour rate, and weighs 162 lbs. They are wired in series with #2/0 (67 mm^2) cable, and are paralleled with #4/0 (107 mm^2) cable.

Because of physical layout considerations, the batteries are configured in two groups of twelve. These are both wired in parallel to the same solid copper positive and negative bus bars. Each twelve-battery grouping is configured as three parallel 48 VDC battery strings. The two sub-banks are tied to the bus bar through a pair of 300 amp class-T fuses. The batteries in each sub-bank are cross-tied with #4 (21 mm^2) cable to help balance charging. The E-Meter tracks all the power in and out of the battery bank. The DS-1000 DeSulfator should help control battery sulfation.

Who are all these solar bozos?

Inverters

The two inverters, which are not stacked, power all the 120 VAC loads in our home. Each inverter generates pure 60 Hz, 120 VAC sine wave electricity (3–5% THD). These inverters are really power conversion centers. They not only convert battery voltage into sine wave household voltage, but are also capable of recharging the batteries from a backup generator or from utility power. They can also sell excess power back to the utility.



Bell System Costs

Wind System

Item	Cost (US$)
Jacobs wind turbine*	$6,500
Tower kit, including 7 foot stub tower*	6,088
Sandblasting and painting*	1,160
1,000 feet #2/0 USE cable	1,126
Concrete	1,120
Welding*	1,000
8,000 pound 48 VDC winch	1,000
108 feet of 8 inch schedule 40 steel pipe	800
Trenching and backhoe*	525
Two C-40 diversion controllers	280
Miscellaneous hardware	200
Fused disconnect box	120
Heavy duty dump load, home-built	0
Tracker PV System	
16 Siemens SM-55J solar modules	$5,040
Wattsun dual-axis tracker	1,660
Concrete	280
Wiring and conduit	250
Fused combiner box	120
20 feet of 6 inch schedule 40 steel pipe	100
Roof PV System	
28 Siemens SP-75 solar modules	$10,136
Module mounting racks	964
2 Solar Converters MPPT charge controllers	616
Fused combiner box	270
Wiring and conduit	250
Battery Storage System	
24 Concorde PVX-12255 batteries	$8,585
Battery box materials	470
Battery cables	450
E-Meter with pre-scaler	270
DeSulfator, DS-1000	113
Safety fusing	90
Miscellaneous cable and conduit	70
Inverters & AC System	
Trace SW5548 with conduit box	$2,885
Trace SW4048 with conduit box	2,460
Dual DC250 with additional breakers	442
Manual AC transfer switch	150
Miscellaneous wiring and conduit	125
AC subpanel	40
Illinois sales tax ($40,482 total taxable)	$2,530
Total System Cost	$58,285

* 6.25% sales tax does not apply to these items.

Illinois State Incentive Money for RE

The Department of Commerce and Community Affairs (DCCA) of the State of Illinois has begun one of the most RE-friendly incentive programs in the country.

The DCCA administers the Renewable Energy Resources Program (RERP) in order to foster investment in and development of renewable energy resources within the state of Illinois. The RERP will fund projects focused on increasing the utilization of renewable energy technologies in Illinois (estimated at US$5 million per year for five years pending legislative changes). RERP will include wind, solar, thermal energy, photovoltaic systems, dedicated crops grown for energy production, organic waste biomass, and hydropower that does not involve new construction or significant expansion of hydropower dams.

There are two components to the program—grants and rebates. To apply for a grant or rebate, a potential recipient must be within the service territory of an investor-owned electric or gas utility, a municipal gas or electric utility, or an electric cooperative that imposes the Renewable Energy Resources and Coal Technology Development Assistance Charge (as defined in Public Act 90-561).

Grant funding categories are as follows:

- Wind—50 percent, with a maximum grant of US$300,000
- Solar Thermal—50 percent, with a maximum of US$150,000
- PV—60 percent, up to US$6 per watt with a maximum of US$300,000
- Crops—50 percent, with a maximum of US$150,000
- Organic Waste Biomass—50 percent, with a maximum of US$550,000
- Hydropower—50 percent, with a maximum of US$1,000,000

Rebates are funded as follows:

- Solar Thermal—50 percent, with a maximum rebate of US$5,000
- PV—60 percent, up to a maximum of US$6 per watt, with a maximum rebate of US$5,000

Note: Steve Bell was the first grant recipient in the state. Mark Wilkerson, whose related article is on page 20, was the first rebate recipient. Much hurdle clearing has been done for anyone else in the state interested in this very generous incentive to "go solar."

The inverters get their DC input via two 250 amp DC breakers connected to the positive bus bar with #4/0 (107 mm^2) cable. The two inverters (SW4048 and SW5548) are not stacked, although they can be if I have the need. Each inverter powers one side of the AC subpanel (There are no 220 VAC loads on the system). With a minor wiring adjustment, either inverter is capable of powering the entire household should one of them fail.

Each inverter has access to grid power via its own 60 amp breaker in the utility breaker panel. The AC output of the inverters is fed into a manual transfer switch, which then feeds the sub-panel. A separate pair of 60 amp breakers in the main (utility) panel also feeds power to the manual transfer switch. That allows easy transfer of the subpanel (house loads) back onto grid power should the RE act up.

Loads

This system provides power for all the 120 VAC loads in our home. These loads include two freezers, a 22 cubic foot (0.62 m^3) refrigerator/freezer, 1/3 hp sump pump, 32 inch (81 cm) color TV, 150 watt stereo, microwave, all the lighting loads, and anything else we plug into the wall.

The battery storage bank can supply the household needs for six to eight days of no wind or PV power before it requires recharging from an outside source. The AC power supplied from the inverter is cleaner than the power supplied from the utility; there are no brownouts, surges, spikes, or power outages.

Stewards

Over the years, many people have asked why we chose to go with RE—what is the payback? I explain that economic payback was not a significant consideration when making this choice. Our choice was based on the desire to be better stewards of the planet, and to increase our sense of self-empowerment (taking more direct responsibility for our lives).

We in the RE community are the “way-showers” of a new way of being and living. We are willing to accept the added economic cost of using RE in order to demonstrate in our lives that RE is a practical choice and a livable reality. We are the future!

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